

# THE IDENTITY OF FALKMANITE AND YENERITE WITH BOULANGERITE

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## ABSTRACT

Two recently named lead sulphantimonite minerals, falkmanite and yenerite, are re-examined. X-ray powder patterns are indistinguishable from that of boulangerite. Structural lattice dimensions, deduced from x-ray rotation and Weissenberg photographs, agree with those of boulangerite within limits of accuracy of measurement. Other properties supposed to distinguish the three minerals are critically reviewed.

## INTRODUCTION

Nearly twenty mineral names have been proposed for minerals belonging to the Pb-Sb-S system. The two most recent of these, falkmanite ( $12\text{PbS}\cdot 4\text{Sb}_2\text{S}_3$ ) described by Hiller (1939) and by Ramdohr and Ödman (1940), and yenerite ( $11\text{PbS}\cdot 4\text{Sb}_2\text{S}_3$ ) described by Bayramgil (1945), appear to differ very little from boulangerite ( $10\text{PbS}\cdot 4\text{Sb}_2\text{S}_3$ ) as described by Berry (1940) and Palache and Berman (1942). In the course of an investigation of the Pb-Sb-S system (Robinson 1948) the writer was unable to confirm either of these new species; it was felt, therefore, that further examination of natural type material was warranted.

A type specimen of yenerite from Isikdag, Turkey, collected and described by Bayramgil (1945) was obtained through the kindness of Professor Reinhard, Basel. For specimens of falkmanite from the Bayerland Mine, Bavaria, and from Boliden, Sweden, the writer is indebted both to Professor Ramdohr, Berlin, and jointly to Professor Quensel and Dr. Ödman, Stockholm. Unfortunately the specimens of falkmanite from Minas Geraes which Hiller carried out his x-ray investigation were destroyed during the war. Professor Berry, under whose supervision this work was carried out, was also kind enough to make available his original x-ray photographs of boulangerite. For purposes of comparison, specimens of boulangerite from the Sullivan Mine, British Columbia, supplied by courtesy of the Consolidated Mining and Smelting Co., were used. These clean acicular crystals were analyzed by J. R. Williams & Son, Vancouver, B. C. (Warren & Thompson 1944, p. 82).

Examination of yenerite and falkmanite was restricted to determination of such data as may be evaluated from x-ray powder, rotation, and Weissenberg photographs. For this purpose filtered CuK radiation was employed in powder photographs and unfiltered CuK radiation for rotation and Weissenberg photographs. Camera radius in all cases is  $90\pi$  mm. (1 mm. on film =  $1^\circ\theta$ ).<sup>1</sup> In x-ray powder photographs of minerals

<sup>1</sup> Each camera was calibrated by measurement of x-ray photographs of calcite.

such as boulangerite, which are markedly acicular in habit, the effect of preferred orientation of many individual particles in the powder specimen frequently gives rise to divergences in the proper intensity of diffractions from planes in the zone parallel to the direction of elongation of the mineral, relative to those from other planes. Particular care was taken in preparation of powder "spindles" both to reduce this phenomenon to a minimum and also to attain approximately equal thickness of powder specimens.

Since the x-ray powder pattern of falkmanite is described by Hiller (1939) as being identical with that of boulangerite, and that of yenerite is said to differ only slightly (Bayramgil 1945), rotation and Weissenberg photographs of each were also taken. These were both measured and compared directly by superposition on a screen with the corresponding photographs of boulangerite.

#### DESCRIPTION OF SPECIMENS

Yenerite, in the one specimen available, occurs as a mass of loose felted hair-like crystals in a vug with euhedral quartz crystals. It is found also as needles in quartz associated with subhedral pyrite, euhedral arsenopyrite, and massive sphalerite, in a rather friable quartz and calcite gangue.

Falkmanite forms the bulk of the specimens both from Bayerland and Boliden. Typically it appears in sub-parallel bundles of fibres, such bundles commonly being so oriented as to yield a mosaic appearance. In polished section its association with chalcopyrite, pyrite, galena, and bournonite has been well illustrated in photographs of polished sections in the paper by Ramdohr and Ödman (1940). The bournonite veins chalcopyrite, these veins extending into fractures in the falkmanite caused by flexing of the parallel bundles; in both cases replacement by bournonite is indicated. Galena appears commonly as rounded "remnants" in falkmanite and as irregular rounded or elongated inclusions down to sizes barely resolved under magnification of 50 diameters. This distribution of galena is common in varying amounts to all available specimens of falkmanite, both from Bayerland and Boliden.

#### X-RAY ANALYSIS OF BOULANGERITE, FALKMANITE AND YENERITE

X-ray powder patterns of yenerite, falkmanite, and boulangerite are identical except for barely discernible differences in intensity due to preferred orientation of particles in the specimen. Similar variations in intensity have been demonstrated in two powder "spindles" made up from identical material. X-ray powder photographs of the three minerals are reproduced in Figures 1, 2, 3, 4. Identity is best established by direct

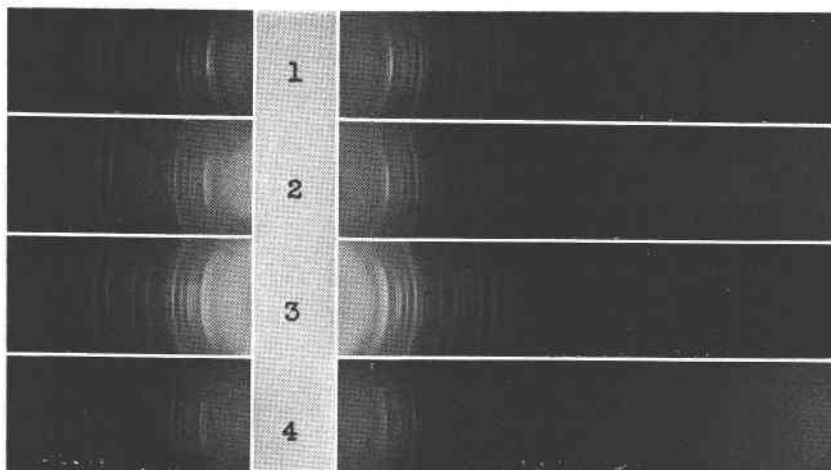


FIG. 1-4. X-ray powder photographs with Cu radiation (Ni filter); camera radius  $90/\pi$  mm. (1 mm. on film =  $1^\circ\theta$ ); full size reproductions of contact prints.

FIG. 1. Boulangerite, Sullivan Mine, Kimberley, B.C.

FIG. 2. Yenerite, Isikdag, Turkey.

FIG. 3. Falkmanite, Bayerland Mine, Bavaria, Germany.

FIG. 4. Falkmanite, Boliden, Sweden.

comparison using a screen with a cursor; the differences in spacing of lines in Table 1 are, in fact, due to the limited accuracy of measurement.

Spacings for the different planes corresponding to these diffractions, calculated from measured dimensions of the unit cell of boulangerite have already been published (Berry 1940, Table 2, pp. 14-15). Several lines in addition to those listed by Berry are included in the above table; each of these was found in more than one *x*-ray powder photograph.

The possibility exists that two minerals which are chemically and structurally similar, may yield *x*-ray powder photographs in which differences are so slight as to be barely discernible,<sup>2</sup> particularly when such differences may be attributable either to preferred orientation or to diffractions from minor impurities. In such cases it is necessary to employ *x*-ray rotation photographs and Weissenberg resolutions of the various layers. Such photographs can be indexed and diffractions due to extraneous causes are then readily recognized.

Rotation and Weissenberg photographs of the zero, first, and second layers were made and indexed for boulangerite and yenerite. In the case

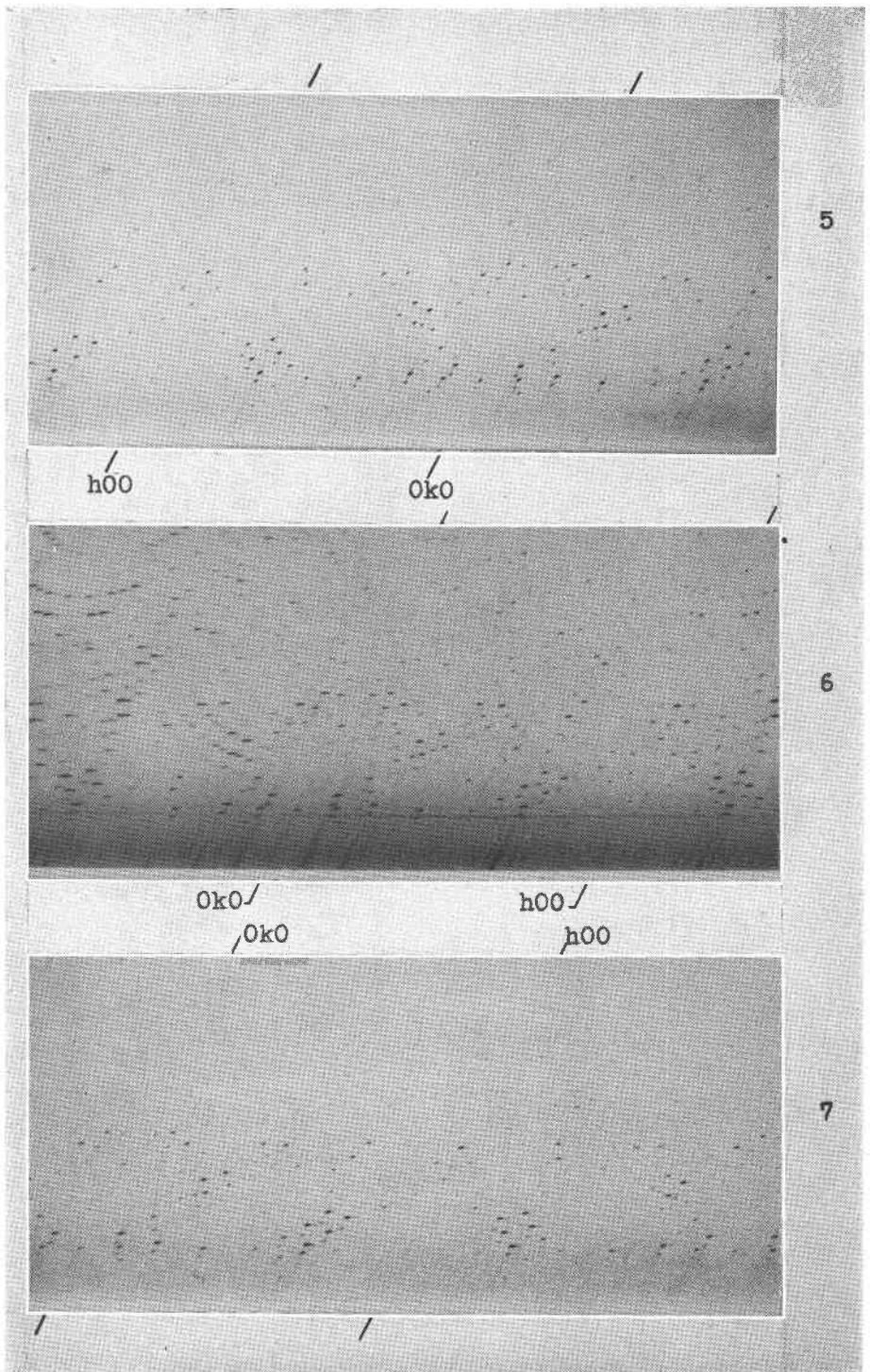
<sup>2</sup> Such a case is well illustrated by similarity in *x*-ray powder photographs of andorite, ramdohrite and fizelyite (Nuffield 1945).

TABLE 1. X-RAY POWDER PHOTOGRAPHS  
 Diffractions having glancing angles  $\theta$  (Cu) less than 38.45 only

1		2		3		4			5		6	
<i>I</i> $\rho$	$\theta$ (Cu)	<i>I</i> $\rho$	$\theta$ (Cu)	<i>I</i> $\rho$	$\theta$ (Cu)	<i>I</i> $\rho$	$\theta$ (Cu)	<i>d</i> (meas.)	<i>I</i> $\rho$	$\theta$ (Cu)	<i>I</i> $\rho$	$\theta$ (Cu)
—	—	1/2	6.6°	—	—	1/2	6.55°	6.74 kX	—	—	—	—
—	—	1	7.3	—	—	1	7.2	6.13	—	—	—	—
—	—	—	—	—	—	1/2	8.5	5.20	—	—	—	—
—	—	—	—	—	—	1/2	9.1	4.86	—	—	—	—
—	—	—	—	—	—	1/2	9.6	4.61	—	—	—	—
1/2	10.2°	1	10.15	1/2	10.51°	1	10.15	4.36	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	vvw	10.8°
2	11.4	2	11.4	2	11.4	2	11.4	3.89	vw	11.3°	vw	11.4
10	11.95	10	11.95	10	11.95	10	11.95	3.71	vvs	11.9	s	12.0
1	12.95	1	12.95	1	12.95	1	12.95	3.43	vvw	12.9	—	—
3	13.4	3	13.4	3	13.45	3	13.4	3.32	vw	13.4	—	—
5	13.85	5	13.85	4	13.9	5	13.85	3.21	m	13.8	—	—
4	14.7	4	14.75	3	14.8	4	14.75	3.02	m	14.8	m	14.9
8	15.85	8	15.85	8	15.85	8	15.85	2.815	vvs	15.85	s	15.9
3	16.6	3	16.55	2	16.65	3	16.6	2.691	w	16.8	m	16.7
1	17.35	1	17.35	1	17.35	1	17.35	2.578	vvw	17.3	vw	17.3
1/2	17.85	—	—	1/2	17.85	1/2	17.8	2.515	—	—	—	—
1/2	18.35	1/2	18.45	—	—	1	18.4	2.435	—	—	—	—
—	—	—	—	—	—	—	—	—	vvw	19.0	—	—
6	19.2	6	19.15	6	19.25	5	19.2	2.337	vw	19.3	m	19.2
6	19.45	—	—	—	—	1/2	19.5	2.303	—	—	—	—
1/2	20.15	1/2	20.15	1/2	20.25	1/2	20.2	2.226	—	—	m	20.2
5	20.95	4	21.0	5	21.05	4	21.0	2.145	w	21.1	m	21.1
—	—	1/2	21.45	—	—	—	—	—	—	—	—	—
1	21.95	2	22.05	2	22.0	2	21.95	2.056	w	22.1	s	22.1
1	22.95	1/2	23.0	1	23.1	1	23.0	1.967	vvw	23.1	vw	23.2
3	23.6	2	23.65	3	23.65	2	23.6	1.920	m	23.6	m	23.7
7	24.35	7	24.45	7	24.45	7	24.4	1.861	vvs	24.3	vs	24.5
—	—	1/2	24.95	—	—	1/2	24.85	1.829	—	—	vw	25.0
7	25.95	6	25.95	6	26.0	6	25.95	1.757	s	26.0	s	26.0
2	26.45	1	26.45	1	26.45	2	26.45	1.726	m	26.4	—	—
2	27.55	2	27.55	—	—	1	27.45	1.668	—	—	—	—
—	—	—	—	2	27.65	2	27.65	1.657	—	—	vvw	27.6
1	29.05	1/2	29.0	1/2	29.0	1/2	28.95	1.588	—	—	vvw	29.1
—	—	—	—	1/2	30.1	1/2	30.0	1.537	—	—	vvw	30.3
—	—	—	—	—	—	1	30.75	1.504	—	—	—	—
2	31.6	1	31.75	1	31.75	1	31.65	1.465	w	31.4	m	31.6
—	—	—	—	—	—	—	—	—	—	—	vw	32.5
3	33.05	2	33.1	3	33.1	2	33.1	1.408	s	33.0	s	33.2
1	33.8	1/2	33.95	1	33.95	1	33.9	1.378	—	—	vw	33.9
—	—	—	—	—	—	—	—	—	—	—	vw	35.4
1	36.1	1	36.05	1	36.25	1/2	36.15	1.303	m	36.1	m	36.4
1	38.3	1	38.4	1	38.45	1	38.35	1.239	m	38.1	s	38.4

1. Falkmanite, Bayerland Mine, Bavaria.
2. Falkmanite, Boliden, Sweden.
3. Yenerite, Isikdag, Turkey.
4. Boulangerite, Sullivan Mine, Br. Columbia.
5. Boulangerite, Mullan Idaho (Berry 1940).
6. Boulangerite, Hiller (Berry 1940).

*I* $\rho$ —Intensity estimated visually.  
 $\theta$ (Cu)—Glancing angle corrected for divergence in camera radius from  $90/\pi$  mm. and for film shrinkage.  
*d*(meas.)—Planar spacing (Å).



FIGS. 5-7. Weissenberg resolutions of the zero-layer-line about the needle-axis [001]; Cu radiation unfiltered; full size reproduction of contact prints.

FIG. 5. Yenerite, Isikdag, Turkey.

FIG. 6. Boulangerite, Mullan, Idaho.

FIG. 7. Falkmanite, Bayerland Mine, Bavaria, Germany.

of falkmanite, rotation and zero-layer photographs only were made. These single crystal photographs of the zero-layer with rotation about the axis of elongation (*c*-axis) for crystals of boulangerite and yenerite and for a crystal fragment of falkmanite are illustrated in Figures 5, 6, 7. In all cases the relative photographs of all three are identical both in relative intensity and in spacing. This fact is best established by superposing one photograph upon the other; differences in the following table of elements of the unit cell are entirely due to limitations in accuracy of measurement of the photographs.

TABLE 2. CELL DIMENSIONS OF BOULANGERITE, FALKMANITE, AND YENERITE

Specimen	<i>a</i>	<i>b</i>	<i>c</i>	$\beta$
Boulangerite (Sullivan)	21.46 kX	23.49 kX	8.07 kX	100° 50'
Boulangerite (Berry 1940)	21.52	23.46	8.07	100 48
Falkmanite (Bayerland)	21.53	23.49	8.08	100 49
Falkmanite (Bayerland)	21.49	23.46	8.07	100 49
Yenerite (Isikdag)	21.47	23.44	8.08	100 51

Indexed reciprocal lattice projections of Weissenberg resolutions of the zero, first and second layer lines of boulangerite and yenerite show that systematically missing reflections conform to the conditions: *hOl* present only with *h* even; *0k0* present only with *k* even. These conditions coincide with those determined by Berry (1940) for boulangerite from Mullan, Idaho, and are characteristic for the space group:  $C_{2h}^5 - P2_1/a$ .

#### REVIEW OF SOME OF THE CRITERIA ADVANCED FOR DISTINCTION BETWEEN BOULANGERITE, YENERITE AND FALKMANITE

A review of Hiller's *x*-ray work on falkmanite shows that while he found the *x*-ray powder patterns of falkmanite and boulangerite to be identical, he obtained monoclinic elements for falkmanite as compared with his earlier and incorrect orthorhombic elements for boulangerite. His falkmanite elements roughly correspond in two dimensions and the  $\beta$  angle with the true elements for boulangerite, although his setting differs. In view of his erroneous results on boulangerite and other minerals (Berry 1943 footnote, p. 19), it seems possible that his values for falkmanite are equally in error.

X-ray analysis of yenerite in the original paper rests entirely on minor differences between its powder pattern and that of boulangerite. These differences may be due to preferred orientation or to impurities in one specimen or the other. Neither in falkmanite nor in yenerite was any attempt made to verify the powder pattern by calculation of spacings based on elements of the unit cell.

Although this investigation has been limited to such properties as may be obtained from *x*-ray analysis, some comment may be advisable also regarding other criteria on which determination of falkmanite and yenerite rests.

In both cases chemical analysis indicates higher lead content than is required for boulangerite, but in both cases the material analyzed contained minerals other than falkmanite and yenerite, respectively. In both cases, too, galena is closely associated with the sulpho-salt; in eight polished sections of type falkmanite from Boliden and Bavaria no single area was found to be free from interstitial galena. While Ramdohr and Ödman (1940) do note the presence of galena, apparently they did not make any correction for it in recasting their analysis.

Bayramgil (1945) considers that his determination of specific gravity corroborates a lead-content in yenerite greater than that of boulangerite and proposes the use of specific gravity determination as an indication of composition for the lead sulphantimonites. In his graph illustrating this suggestion, Bayramgil shows specific gravities of boulangerite 5.79, falkmanite (Hiller) 6.23 and yenerite 6.05. Ramdohr and Ödman (1940) record 6.195 and 6.20 as the specific gravity of falkmanite. Most recent determinations of specific gravity of boulangerite (Palache, Berman and Frondel 1944 p. 421) are 6.23 and 5.98 (measured) and 6.21 (calculated). Thus the measured specific gravity of both falkmanite and yenerite falls in the range of recent determinations for boulangerite.

The writer considers that the data presented above adequately establish the mutual identity of boulangerite, falkmanite, and yenerite. Since the name boulangerite has precedence in the literature it is suggested that it be retained and that the names falkmanite and yenerite be discarded.

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